AFRL-IF-RS-TR-2002-194
Final Technical Report
August 2002

REPRESENTING AND REASONING WITH DESIGN RECORDS FOR EVOLUTIONARY SYSTEMS

Georgia State University

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AIR FORCE RESEARCH LABORATORY
INFORMATION DIRECTORATE
ROME RESEARCH SITE
ROME, NEW YORK

This report has been reviewed by the Air Force Research Laboratory, Information Directorate, Public Affairs Office (IFOIPA) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be releasable to the general public, including foreign nations.

AFRL-IF-RS-TR-2002-194 has been reviewed and is approved for publication

APPROVED: John J. Crowter

JOHN J. CROWTER
Project Engineer

FOR THE DIRECTOR: Michael Talbert

MICHAEL L. TALBERT, Technical Advisor
Information Technology Division
Information Directorate

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	AUGUST 2002	Final Feb 98 – Dec 98

4. TITLE AND SUBTITLE
REPRESENTING AND REASONING WITH DESIGN RECORDS FOR EVOLUTIONARY SYSTEMS

5. FUNDING NUMBERS
C - F30602-98-C-0047
PE - 62702F
PR - 5581
TA - 27
WU - P1

6. AUTHOR(S)
Balasubramaniam Ramesh

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Georgia State University
Office of Sponsored Programs
University Plaza
Atlanta Georgia 30303

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory/IFTB
26 Electronic Parkway
Rome New York 13441-4514

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
AFRL-IF-RS-TR-2002-194

11. SUPPLEMENTARY NOTES

AFRL Project Engineer: John J. Crowter/IFTB/(315) 330-1459

12a. DISTRIBUTION / AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

12b. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 Words)***
In the context of evolving missions and radical changes in the strategic and operational environments in the DoD, the ability to understand the rationale behind key decisions and evaluate the repercussions of changes in underlying assumptions and requirements will be very valuable to key decision makers. In this research we propose to develop models and mechanisms necessary to provide comprehensive Design Records (DR) that help understand, evaluate and reuse critical decisions in complex problem solving situations such as the specification and development of C4I systems. Based on theoretical and empirical studies, model(s) to represent critical components of the rationale behind critical decisions have been developed. Mechanisms designed to support the needs of various stakeholders involved in the decision making process are discussed. A prototype decision support system that incorporates these models and mechanisms to support the capture and use of design records is discussed with examples drawn from the context of the design of information products. Additional examples drawn from various system development scenarios are also discussed in Appendix 1.

14. SUBJECT TERMS
Software Systems, Evolutionary Systems, Software Design, Software Requirements, Software Tools

15. NUMBER OF PAGES
44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

Table of Contents

List of Figures

List of Tables

Abstract

In the context of evolving missions and radical changes in the strategic and operational environments in the DoD, the ability to understand the rationale behind key decisions and evaluate the repercussions of changes in underlying assumptions and requirements will be very valuable to key decision makers. In this research we propose to develop models and mechanisms necessary to provide comprehensive **Design Records (DR)** that help understand, evaluate and reuse critical decisions in complex problem solving situations such as the specification and development of C4I systems. Based on theoretical and empirical studies, model(s) to represent critical components of the rationale behind critical decisions have been developed. Mechanisms designed to support the needs of various stakeholders involved in the decision making process are discussed. A prototype decision support system that incorporates these models and mechanisms to support the capture and use of design records is discussed with examples drawn from the context of the design of information products. Additional examples drawn from various system development scenarios are also discussed in Appendix I.

1. Introduction

Organizational memory provides the means by which organizational knowledge from the past can influence the present organizational activity. It is stored information from an organization's history that can be brought to bear at present decision. Recent literature emphasizes the importance of mechanisms to capture and manage rationale in situations involving large number of participants involved in complex organizational processes like large-scale systems development [8]. In collaborative activities involving a large number of participants, each having a different set of goals and priorities, maintaining a comprehensive history can be invaluable. Such a history is an important component of OM and includes various types of memory which has been called Group/team memory, design rationale/discussion memory, and project memory. In this report, we take this limited, task specific view of Organizational Memory, recognizing that a comprehensive organizational memory includes information retained by individuals, culture, transformations, structures and ecology.

A variety of stakeholders involved in organizational decision processes bring together their often unique viewpoints and expertise. These range from top management providing inputs on the nature of the problem and its impact on the organizational goals, to middle managers who help articulate objectives and constraints, to lower level workers that implement them. In contexts where tightly integrated decision processes across functional boundaries cannot be easily developed and implemented, organizational memory that provides a loose coupling between relevant decision situations can greatly enhance shared understanding across these boundaries. Coordination among the various stakeholders which is critical to success can be facilitated with organizational memory that integrates their various perspectives. A basic premise in our work is that for each of the stakeholders involved in such processes, some useful support can be provided by recording in some structured fashion relevant portions of organizational memory.

Recent studies confirm that capturing organizational memory is especially important in large-complex activities for the following reasons:

- The context in which key decisions are made will be lost when different teams are engaged in various aspects of the organizational process.
- Critical errors are commonly made in formulation and resolution of decisions, but they are often unnoticed in the absence of comprehensive organizational memory
- In the absence of reliable organizational memory, work groups engage in repetitive discussion and resolution of the same issue
- When stakeholders with differing expertise, perspective and viewpoints are involved, key decisions are often misunderstood and misinterpreted

Recent research argues that complex decision making situations involve a constantly changing environment and preferences. Further, these situations are also characterized by incomplete and even inaccurate information. In such complex decision situations, a comprehensive organizational memory of the context in which decisions are arrived at and the ability to *understand and analyze* its implications when it changes will be extremely helpful The need to capture and reason with the information regarding the *context* is even more pronounced when the decision making includes participants from various functional domains. OM that provides the ability to modify and manipulate decisions in response to changing requirements and assumptions are valuable in diagnostic problem solving.

A major challenge in this research is to represent relevant parts of OM to facilitate shared understanding and use of multiple stakeholders in complex problem solving activities. In this proposal, we focus on capturing and using the rationale behind critical decisions (called design records) [1]. In this section we examine the nature of such activities to identify the characteristics of OM that must be captured. We highlight the implications for the representation and acquisition of OM. The capabilities for a prototype Organizational Memory System (OMS) that facilitates the acquisition, maintenance and use of OM, automated tools for supporting the needs of various stakeholders will be developed in this research.

2. Characteristics of a Design Records (OMS)

2.1 Managing Conflicts

Complex decision making situations involve a multitude of trade-offs across and within functional domains. When multiple stakeholders participate in collaborative activities, they can disagree on a wide range of issues due to differences in goals, the information available, and the understanding of the task. Some conflicts may arise when stakeholders differ in their respective interests, whereas others may be caused by the fact that different parties in a team can bring to bear different and often incomplete views of the task.

Conflicts arise even when stakeholders do not differ in their respective utilities, but simply because they offer multiple cognitive perspectives on the problem. Such conflicts are called judgement conflicts or cognitive conflicts and they "play a major role in a number of models of decision-making". Judgement conflicts can arise when, even in the same domain, different experts use different set of variables to perform their tasks. Successful collaborative activities require a co-evolution of personal understanding of the participants and the shared understanding of the group. This problem is exacerbated when the participants are interested in understanding the context or history of their task situations. Therefore, it is essential to explore mechanisms to manage judgement conflicts so that relevant information can be captured in OM to facilitate shared understanding.

The management of judgement conflicts can be thought of as an iterative process of convergence at two levels: a collective reconceptualization of the task, and convergence with respect to the importance of different variables used in the solution space. However, as research on expertise and on human information processing suggests, this is difficult because,

---

[1] The terms **organizational memory, design records and decision rationale** are used interchangeably in this report.

in large part, human decision behavior is implicit and automatic, and thus difficult to articulate and convey. In addition, certain types of information are often not articulated at all because they are perceived as being "obvious" within a particular functional domain (whereas they may not be obvious at all to participants from other domains).

The need to support sensemaking, a process of negotiation and construction of a mutually shared agreement of what causal linkages and outcome preferences constitute a confusing event, is well recognized. They argue for supporting the strategies of action, triangulation, affiliation, deliberation and contextualization. Action can be facilitated when the support system can be used in the context of actual work rather than in an isolated decision support facility. Triangulation can be facilitated by providing access to diverse information sources in a variety of formats. Affiliation can be facilitated with aids for building shared interpretation. Providing access to group memory consisting of artifacts produced during meetings can facilitate deliberation. Contextualization can be aided by providing access to context in “constructing causal linkages, outcome preferences, and shared interpretations”. Recent work also warns against creating support systems that increase meeting pace, decrease social interaction, prevent emergent approaches, and isolate participants from events, because they impede sensemaking.

2.2 Implications for Design Records OMS

Contents of OM. It is suggested that complex tasks such as those involving the deliberation process of assumption surfacing, information exchange and reconceptualization be supported with appropriate cognitive artifacts for representing thought and exchanging ideas. Researchers in social judgment theory have conceptualized cognitive feedback as a generalized term for cognitive artifacts appropriate for managing judgement conflicts. An important issue for the development of OM is the identification of information that should be provided as part of cognitive feedback. Cognitive maps characterizing the context of a decision situation have been used to address this issue. A dependency mechanism would maintain interdependencies, and thus provide information about the task environment. This would help a participant become familiar with the relevant aspects of other functional domains. Finally, the system could help in reconceptualizing the solution space by providing feedback on assumptions that are in conflict.

Effective integration of various viewpoints can be accomplished through the use of three design principles: flexibility in capturing and presenting information, ownership of representations, and maintaining context. At the individual level, context - as often driven by the functional domain - is present in an implicit fashion. However, this context is often lost in the transition to the interpersonal or collective level, when domains are traversed. The effectiveness of OMS can be enhanced if they are designed to provide and maintain context. For example, the ability to bring otherwise implicit assumptions to the surface could be a useful way to maintain context in the transition between levels.

In summary, the above discussion suggests that components of OM should include rich contextual information not only to provide detailed viewpoints of individual decision-makers, but also to identify interdependencies among differing perspectives and viewpoints. Providing such comprehensive traceability (which we define as the capability to relate an OM component to its sources, refinements and use) will greatly enhance the usefulness of OM.

Representation of OM. An important issue brought out by the above discussion is the choice of representation for OM. Organizational memory can be represented at different levels of formality, from "mathematically" formal representations (e.g., transformations that can formally derive one design state from another in a formal specification based systems development environment) to very informal representations (e.g., design notebooks that record the progression of steps and other relevant information in natural language).

Formal representations of OM facilitate automated reasoning. In large complex organizational processes where the size and complexity of OM can grow rapidly, facilities for automated reasoning can be very valuable. However, formal representations of OM have several limitations. They are feasible only in domains that have formal domain models, and in tasks where the semantics are well defined. The domain knowledge needed to create formal representations, thus, is not readily available in most situations. Another important consideration in the choice of representation is that much of the informal information does not lend itself to formal representation.

Informal representations, though not amenable for automated reasoning, have some advantages. Much of the OM can be more easily captured through informal means. Second, informal representations enable the retention of information in its most complete form, thereby facilitating the creation of thick descriptions.

In summary, then, formal and informal representations of OM complement each other in their respective strengths and weaknesses. Informal representations are easy to capture, whereas formal representations can be manipulated by well-defined reasoning facilities.

2.3 Common Approaches

Several models and systems that support the acquisition and use of OM have been developed recently. Systems such as gIBIS (Conklin and Begeman, 1988) and others that are inspired by it (e.g., IBE [16]), advocate the representation of informal information as a part of a comprehensive OM. These systems provide a hypertext interface to the IBIS model and are constrained by the limitations of IBIS such as the lack of representation of inputs and outcomes of argumentation. In contrast, we argue for a generic framework that can be tailored to support a variety of models such as IBIS and its extensions (such as REMAP that overcome some of its limitations).

A few proposals for capturing the history of complex organizational processes have been made (Ramesh and Dhar, 1992). This research emphasizes the need for access to history of organizational decisions. Our work intends to extend the scope and nature of process knowledge captured so that a variety of stakeholders can be supported in different ways in their tasks. We argue for a generic framework, so that a rich history of knowledge about decisions, various alternatives that may have been considered and discarded, the organizational context which lead to various components of the scenarios and rationale can be captured and reasoned with.

Many groupware systems (such as GroupSystems, VisionQuest) focus primarily on capturing informal knowledge. OMS such as Constellations facilitate access to informal knowledge by chunking multimedia information. The need to integrate informal information in hypertext with formal models in model management has been suggested in the literature. Our work takes a more comprehensive approach to dealing with informal information advocating the creation of formal models to facilitate better integration. Further, instead of maintaining a passive history (as in IBIS and QOC), our focus is on providing intelligent support by maintaining an active history. Our approach provides the opportunity to expand the scope of integration to include much *fuzzier* contextual information and formalizing this information whenever feasible. We suggest a much tighter integration of formal and informal components of OM. Such systems can be integrated with our system to provide fine-grained access to informal OM. Also, as the capture and use of OM can add significant overhead to the stakeholders using them, an OM system should provide automated reasoning to support various stakeholder needs.

2.4 Our approach

A major challenge in this research is to represent relevant parts of design records to facilitate shared understanding and use of multiple stakeholders in complex problem solving activities. An important feature of our technical approach is that we suggest that components of design records should include rich contextual information not only to provide detailed viewpoints of individual decision-makers, but also to identify interdependencies among differing perspectives and viewpoints. Providing such comprehensive traceability (i.e., the capability to relate a critical decision its sources, refinements and use) will greatly enhance the usefulness of design records.

Further, we propose the integration of formal and informal representations of design records as they complement each other in their respective strengths and weaknesses. Informal representations are easy to capture, whereas formal representations can be manipulated by well-defined reasoning facilities. We provide a generic framework, so that a rich history of knowledge about decisions, various alternatives that may have been considered and discarded, the organizational context which lead to various components of the scenarios and rationale can be captured and reasoned with. Also, as the capture and use of design records can add significant overhead to the stakeholders using them, we have developed a prototype decision support system that provides automated reasoning capabilities to support various stakeholder needs. These include facilities for the maintaining the integrity of the knowlegebase using a reason maintenance system, mechanisms to maintain dependencies among various components of decision records, and making deductive inferences.

3. Development of Information Products: An Example

In this report, we describe the need for representing and using design records and illustrate the functionalities of our decision support environment through an example. We have chosen the design of information products as the example since it highlights all the major issues discussed in the earlier sections.

Design is a knowledge intensive activity, often carried out by distributed teams. For example, information products are characterized by unusual economics of production, need to be delivered within highly compressed time frames, have short life cycles, perish in value quickly and have marginal production costs approaching zero, after the first unit. Such products are often developed by cross-functional and trans-institutional teams that are often geographically distributed. Recent research recognizes the importance of capturing comprehensive history behind the design decision making in such dynamic situations. Based on the characteristics and challenges faced in design activities, we identify the requirements for a decision support system (DSS) for design decision making. Using these goals, we have developed a DSS that supports linking of artifacts to processes, flexible interaction and hypermedia services, distribution annotation and authoring as well as providing visibility of artifacts as they change over time.

Widespread penetration of the Internet has led to an unprecedented increase in the trade of information products. Information products consist of a highly interdependent package of information that is primarily intangible in nature. This implies that they can not be physically inspected before purchase (Koppius, 1999), and that traditional ways of trading them have no advantage over trading them electronically (Koppius, 1999). The Internet has provided a channel for the distribution and trade of such products at low overhead costs (Koppius, 1999; Shapiro and Varian, 1998). When distributed over such a medium, their variable cost or production and distribution approaches zero as the product has no physical form unlike retail packaged software. However, due to their intangible nature, information product markets face severe competitive challenges in comparison to tangible products (Koppius, 1999; Shapiro and Varian, 1998). Shapiro et al. (1998) caution that the low economic cost of reproduction of such products also makes them economically lesser viable. If left to the market place, the price of an information product will be low due to the low marginal cost of reproduction of that product (Shapiro and Varian, 1998).

In the post-industrial era, knowledge-based activities of organizations, including IS organizations, are becoming the primary internal function of firms (Davenport, 1993; Quinn et al., 1996). More of an organization's competencies will center around managing knowledge and knowledge work surrounding the development of its products and services, and this will determine most productivity gains that occur (Davenport et al., 1996) in the information product development (IPD) processes. Development of information products is a knowledge intensive activity (Fielding et al., 1998; Robillard, 1999; Zack, 1999). As a firm gains experience through the development of information products, much of the lessons learned still remain captured as information (Fielding et al., 1998; Robillard, 1999; Zack, 1999) and do not get applied i.e. converted to knowledge (Drucker, 1993). Therefore, it is critical to be able to manage and reapply lessons learned and design decisions made in earlier projects in similar contexts in order to keep fthe product competitively viable.

3.1 Defining Information Products

An information product is defined as a highly interdependent package of information (Fielding et al., 1998). Software engineering products, CD-ROM databases, and Web content are examples of such products (Meyer and Zack, 1996; Robillard, 1999). A more restrictive is provided by Shapiro et al. (1998), where they categorize information products as those products that are capable of being distributed in digital form. In economic terms, the fixed costs involved in producing an information product are very high and the variable costs are relatively low (Shapiro and Varian, 1998). This factors necessitate differentiation among information products, as perfect competition can spell disaster for the producer(s) in the markets for that product (Meyer and Zack, 1996; Shapiro and Varian, 1998).

3.2 IPD as a Knowledge Intensive Activity

Information product markets are dynamic in terms of growth and the pace of new product introduction (Meyer and Zack, 1996). As teams in an organization engage in the development of new products and services, the underlying rationale used to make decisions at various points in the design process need to be effectively captured and reused (Wong, 1988; Yglesias, 1993) to provide support for decisions in later projects or in the production of subsequent product versions (Tiwana and Raven, 1999). This necessitates a closer examination of the role of knowledge in the design process.

Davenport and Prusak (1998) point to the subtle difference between knowledge and information, defining knowledge as *actionable* information. Drucker (1993) also introduces the concept of productivity of knowledge, which he indicates is the deciding factor in the competitive position of a company. Drucker further cautions that knowledge is productive only if it is applied to make a difference in the processes or tasks at hand. This requires systematic and organized application of knowledge to enhance, validate and apply existing knowledge (Drucker, 1993). An excellent characterization of the level of knowledge that is applied to decision making processes is provided by Bohn (1994). As developing organisations move up on this process knowledge scale, developing information products moves up from a learning process to a systematic process that uses insights gained from the development of previous versions of such products (Bohn (1994) describes this as process capability). Recent research in production management in the publishing and design stream points to this transition from a craft (identified by stages 1-4 in Bohn's (1994) process knowledge framework) to process orientation (as characterized by stages 5 through 8 in Bohn's (1994) framework) (Bellander, 1998). Bellander (1998) notes that this transition from a handicraft-based industry to a process industry is not an easy transition.

New information product development often involves cross-functional teams, where different participants join a team with differing viewpoints. Such teams are often characterized by participants who achieve a high level of at-stakeness and synergy from their interactions (Jassawalla and Sashittal, 1998) with other team members. Fielding et al. (1998) suggest that this interaction brings in a need to organize, integrate, filter, condense and annotate collaborative data and other relevant information that these team participants contribute. Court (1997) proposes three broad categories of knowledge that designers use in the process of developing a product as described in Table 1. These broad categories of knowledge along with the requirements of an information product development team provide a better understanding of the role that each such knowledge type plays in the design decision processes that underlie the development of an information product.

Table 1: Types & Characteristics of Knowledge in Information Product Development

Type of Knowledge Classification and Goal	Characteristics and Comments
Application of general knowledge	Knowledge that people gain through everyday experiences and apply without regard to any specific domain they might be working in. This type of knowledge might have no specific or direct relation with the task domain (Court, 1997) that the participant on the IPD team is engaged in.
Developing a synergy of domain specific Knowledge	This type of knowledge is gained through study and experience within a specific domain. Domain specific knowledge is generally improved as the person(s) involved in task domain gain more experience (Court, 1997). Since IPD teams are highly cross functional, links to artifacts and processes are needed to share domain specific knowledge (Fielding et al., 1998). Distributed annotation (Fielding et al., 1998) can also provide support to maintain links to help team members make contextual interpretations for decisions outside their domain of expertise (Iansiti and MacCormack, 1997; Song and Montoya-Weiss, 1998).
Applying and supporting procedural Knowledge	This is gained from experience of undertaking a task within the domain. Court (Court, 1997) suggests that this is a combination of the above two types of knowledge. Procedural knowledge therefore includes domain specific knowledge and domain independent knowledge (Court, 1997; Davidow and Malone, 1992; Leonard and Sensiper, 1998; Nonaka and Takeuchi, 1995). Since expertise might be distributed in an information product development team, the ability to provide distributed authoring (Fielding et al., 1998) and design decision coordination (Faraj, 1998; Fielding et al., 1998) helps bring together existing expertise.

3.3 Characteristics of Information Products

Examination of recent literature on information product development and new product development processes reveals several distinguishing characteristics of information products that makes them different from tangible physical products. We list these characteristics, later followed by an analysis of the problems that result from these rather distinct characteristics. We draw up on a case study of a specific IPD activity (i.e., the development of a newspaper) in our discussion.

A newspaper is released in two different formats – Web and print, typically each morning. This process involves extensive cross functional collaboration on the design on this information product. Critical layout decisions like the relative placement of the weather sidebar or daily sports scores on the front page requires inputs from a diverse variety of stakeholders. These might include editorial, marketing and sales, advertising and management personnel. Further, the product is developed within the span of one day and needs to integrate diverse inputs that its correspondents and news feed services such as Reuters provide. An appropriate balance between what goes on the Web-based version and what goes into the print version, is needed so that “sales” of one version are not cannibalized by the other. For example, news content of the print version can not be cut down extensively since it might affect daily news stand sales. On the other hand the print version should not have too much content that the Web version is missing as that might de-motivate future ‘hits’ from potential readers and Website visitors. Besides content and layout issues, the balance of similarities and differences in the design of the print and the Web version of the newspaper are also critical issues (Cottrell and Faulkner, 1998; Techart, 1993). We will return to this example throughout the rest of this paper to identify problems as well as decision support solutions provided by our research.

Unusual economics of production

Information products have unusual economics of production yet are subject to the same market and competitive forces that govern the fate of any physical product (Shapiro and Varian, 1998; Shapiro and Varian, 1999). In a local newspaper, the first copy involves significant costs and effort. However, every subsequent copy, either print based or Web-based, has negligible marginal cost. In case of the Web-based version of the newspaper, the marginal cost of additional copies is that of retrieving content through a Web browser, which is close to zero.

Timeliness of delivery

Timeliness of delivery of an information product can be a major determinant of its value to the consumer (Ballou et al., 1998), who may be either internal or external to the organization. Ballou et al. (1998) further suggest that a firm can possibly create competitive advantage by delivering an information product in a shorter time-frame than initially targeted. In our case study, the success of a newspaper depends on its ability to deliver news content in its final form *at a minimum*, once every morning. This means that the time frame from product conception to production spans twenty-four hours for most content components.

Short product lifecycles

Information products typically enjoy very short life cycles (Clark and Wheelwright, 1994; Fielding et al., 1998; Iansiti and MacCormack, 1997). Furthermore, the underlying technologies are evolving at a rapid pace, which makes the process lifecycle shorter as well (Davenport, 1993). Therefore, the time available for recouping expenses associated with their development is compressed. In a Web-based news delivery service run by a local newspaper, the lifecycle of this product is one day, after which its economic value, approaches zero.

Cross functional collaboration

In order to respond to competitive challenges and diverse skill sets needed to develop an information product, organizational units have become more closely coupled than in the past, often working in parallel to complete assignments spanning traditional units and functional areas (Iansiti and MacCormack, 1997; Song and Montoya-Weiss, 1998). Leonard-Barton (1998) indicates that the creation of today's complex systems of products requires amalgamation of knowledge from diverse disciplinary and personal skills-based perspectives where creative cooperation is critical for innovation. Physical product development has been classically characterized by intricate interdependencies among areas such as manufacturing, marketing, and packaging. Analogous to this, the development of information products might require collaboration among people from different skill areas and functional units. Decisions, in the case of information products, relate both to their design/ structure and content.

In our example, a critical layout decision such as the placement of the weather forecast requires inputs from editorial, sales, marketing, advertising and weather specialists. These participants need to bring in their past knowledge of the sales impact of both relative placement of this content and the content itself on the front-page. Building a push Web-based delivery news service might need inputs from the technical staff, software coders, hardware specialists who decide on the hardware specifications needed to host such a system, network specialists who provide Web connectivity, creative design artists who work on the aesthetic design aspects and marketing staff that are responsible for generating advertiser revenue.

Ease of versioning

Physical product manufacturers, including those of complex engineering products, have been able to version products and sell them at different price points. For example, Intel sells two versions of its Pentium II processor – a regular version and a feature- disabled one called the Celeron™ at a lower price point. Although these processors are internally identical and cost almost the same to produce, one is sold at a lower price point simply by disabling the internal cache memory section on the chip. While functional versioning of physical products can be expensive, relative costs of versioning information products to create artificial differentiation is lesser expensive (Shapiro and Varian, 1998). Examples of such versioning of information products include trial versions of software programs and Web sites that require a payment in order to access full content. Numerous product derivatives can be creeated from a central repository. In case of a newspaper, for example, a common content base can be used to spin off a print version, a Web based version customized for different markets or locations and a CD- ROM archive of news content.

Inter-institutional collaboration

As products grow increasingly complex, it is becoming inevitable for multiple organizations to be involved in the development of a single product (Iansiti and MacCormack, 1997). This brings together participants spanning multiple functional disciplines and specializations from across multiple collaborating organizations and stakeholder groups. Such traverse institutional participants might come from different cultures and backgrounds. Therefore there is a need to support effective collaboration and knowledge sharing among these participants (Song and Montoya-Weiss, 1998).

For example, different sister newspapers belonging to the same parent company might be collaborating on their news stories. Besides, most newspapers depend on services such as Reuters for their national and international news feed. Weekend comics and daily comic strips come from feature syndicate services etc. Consequently, putting together such an information product requires collaboration traversing several institutions.

Temporary information product development teams

In large development projects, membership of the development team changes both across time and across project phases. As specialized skills are needed, members from within the collaborating organizational units are drawn into the project on an ad-hoc basis and they return to their original units after their tasks are completed (Iansiti and MacCormack, 1997; Quinn et al., 1996). Rapid growth in the consumer market and the specialized skill-sets necessary are critical factors contributing to the severe shortage of qualified personnel and high turnover, especially in high technology areas.

Uncertainty in evolving markets

Due to the rapid pace of change and evolution in the information product markets (as observed by (Meyer and Zack, 1996)), organizations involved in information product development need to cope with a high degree of uncertainty over fundamental issues that normally drive the product development process (Mullins and Sutherland, 1998). Such issues might include the appropriateness of the choice of a certain technology standard over another, the nature and extent of customer needs, uncertainty about the level of resources that must be invested and the timing of commitments (Mullins and Sutherland, 1998). Recent research on knowledge management indicates that a lot can be learned from the experiential knowledge within the firm to help alleviate the uncertainty surrounding such issues (Nonaka et al., 1998; Nonaka and Takeuchi, 1995; Powell, 1998; Powell, 1967; Quinn et al., 1997).

Perishability

Perishability refers to the decrease in the value of a product over a period of time. Assessment of the perishability of an information product has to take into account the specific use for that occasion (Koppius, 1999). This supports our earlier argument that the value of an information product can be a time-dependent function. For example, a Web-based news service's daily content diminishes in value after one day.

Specifiability

Specifiability has been described in literature as the '*complexity of description'* (Malone et al., 1987). Koppius (1999) suggests that the lack of sufficient specifiability of an information product is a major problem in specifying its features. High specifiability is desirable in order to reduce customer uncertainty (Koppius, 1999). Having descriptions and specification from past information products might help specify new products through partial analogy.

These characteristics of information products pose additional challenges, only some of which are common to physical products. These challenges are further compounded when development of the information product is done by a distributed team .

3.3 Challenges Faced by Information Product Development Teams

Distributed collaboration, especially that enabled through the Web as a communications medium, faces limitations of the characteristics of the medium itself (for example, as described in the case of Web-based development by Fielding et al. (1998)). We focus on problems related to distributed coordination and decision making in the process of design decision making through the Web. Recent literature suggests that such teams face the problems identified in the following sections. Each problem is identified with a problem code such as {XX} and these codes are further used to map system goals and enabling technology characteristics (Table 2) that our prototype demonstrates.

Lack of shared understanding {SU}

Teams developing information products (IPs) are drawn from different functional areas and streams of expertise (Iansiti and MacCormack, 1997; Song and Montoya-Weiss, 1998). This creates dependencies among different functional specializations and requires inputs from these constituents to accomplish joint objectives (Ramesh and Tiwana, 1999) relating to IP design. Such team members come with their differences in their understanding and perspectives of the problems faced throughout the design process (Leonard-Barton and Sensiper, 1998). Team members drawn from different disciplines lack an understanding of the critical design factors for functional areas other than their own. Lack of a common vocabulary and limited knowledge of other functional areas that do not fall under the participant's domain creates the need for a shared and co-evolved understanding in order to allow consensus on the design decision making processes (Cross and White, 1996; Webber, 1993).

In our example, there are multiple stakeholders involved in the production of a news service. For design of the product, advertising, editorial and marketing departments need to provide inputs to maximize a common goal: Improved sales and increased customer value. However, these goals might mean different things to participants with differing functional backgrounds. Hence, there needs to be some mechanism to allow the co-evolution of requisite shared understanding.

Loss of design decision context due to changing team membership {LC}

Ad-hoc teams formed for new product development are often dissolved at the end of the project (Ciborra, 1993; Mankin et al., 1996) and team members often get assigned to other projects (Mankin et al., 1996) where their functional expertise is required. When design decisions are made by teams developing an information product, recording the decision without its context is insufficient (Clark and Wheelwright, 1994). While static teams can partially retain the context of their past decisions, recent research suggests that most organizations tend to deploy dynamically collated teams (Mankin et al., 1996; Tjosvold and Tjosvold, 1991). Nonaka and Takeuchi (1995) have suggested the importance and value of recognizing and capturing tacit information - information that can not be transmitted between team members such as know-how, judgement and intuition which together make up a critical component of information that needs to flow between members collaborating within a team. The success or failure of transfer of design knowledge between team members over time partially depends on the effective transfer of the tacit component of knowledge that collaborative information systems do not capture (Davenport and Prusak, 1998). Dell also suggests that the ability to capture learning in organizational units and teams is an essential precedent to meaningful transfer and sharing of knowledge between groups. Therefore, the loss of context of past design decisions poses a threat to the efficient and effective design of newer versions of the product when team membership is not stable.

Reinvention of solutions {RS}

Reinvention is defined as "making as if for the first time something already invented" (Webster, 1999). Development teams reinvent solutions to problems that might have already been solved (Clark and Wheelwright, 1994; Mankin et al., 1996) due to their lack of awareness of historical decisions (Teece, 1998) in other projects both within and outside the organization. Information product development team members might invest resources into solving problems that might have already been solved as work groups often repeatedly discuss the same issues that have been resolved earlier, as no reliable record of these deliberations may exist (Ramesh and Dhar, 1992). Court (Court, 1997) strengthens this argument by suggesting that product designers often tend to use the incomplete information they already possess, which results in designs being generated without the benefit of knowledge, related information and expertise that might already exist within the organization.

Repetition of design mistakes {RM}

Organizations often repeat past mistakes in design decisions (Davenport and Prusak, 1998; Dillon, 1997; Dolan, 1993) because they lack episodic knowledge of mistakes that might have been made in the past (Ramesh and Dhar, 1992; Robillard, 1999). Processes that would support active transfer of knowledge from successful projects to new ones could reduce the extent of repetition of such mistakes (Ramesh and Dhar, 1992). Teece (1998) suggests that innovations, such as (information) product development, involve a considerable degree of uncertainty. Retaining and actively using the knowledge of episodic failures has value in impelling allocation of resources into auspicious directions rather than repeating past mistakes that the existing design team might not be aware of. Having a mechanism to keep track of past design episodes helps maintain traces of abandoned, interrupted and failed decisions (Robillard, 1999).

For example, the news design team might have realized that not placing baseball scores on the opening page negatively affects customer satisfaction and/or sales. If the design team is unaware that it made that mistake, say three years back, it is at risk to make the same design error again.

Skills developed due to collaboration may be lost for subsequent use {LS}

The design team involved in the development of a successful product is often moved to the next high profile project. The expertise gained during development of the product is not readily available to design teams working the subsequent versions of the product during its evolution (Ramesh and Tiwana, 1999). The primary obstacle to successful learning from alliances is the failure to execute the specific organizational processes necessary to access, assimilate, and disseminate alliance knowledge such as that created in team-based projects (Inkpen, 1996). Recent research indicates that the turnover of such personnel and participants poses a threat to the collective knowledge and expertise possessed by the group since much of the knowledge is tacit i.e. situated in the minds of the collaborating personnel (Nonaka et al., 1998; Nonaka, 1989; Nonaka and Konno, 1998; Nonaka and Takeuchi, 1995). Similarly, low turnover allows for the development of organizational knowledge and expertise as well as fostering a high degree of socialization (March, 1991; March, 1999).

Inconsistent versioning of design information {IV}

There is no way to guarantee that the information entered is always up to date unless the upkeep is somehow automated (Teigland et al., 1998).When the same project information, documentation, design or decision outcome artifact is kept at multiple locations, ambiguities about which one is the most current version arise (Ramesh and Tiwana, 1999). The need for redundancy however must be met simultaneously with the need for maintaining consistency across different versions of information that may be possessed by different team members (Sanchez and Heene, 1997). Resources and design decision artifacts need to be shared in a manner that conflicting versions do not hamper the decision making processes (Chang and Jackson, 1996).

Process knowledge might be lost after the project is completed {PK}

In a project oriented team-based organizational structure, skills developed during the collaboration process might be lost after the team is dissolved and redistributed (Mankin et al., 1996). When a team is disbanded, the process knowledge acquired by the team and needed for tasks such as product modification or maintenance is lost for future use (Ramesh and Dhar, 1992). Quinn et al. (1996) suggest that professional know how is developed most rapidly through repeated exposure to the complexity of real problems i.e. experience gained through collaborative work. Recent research suggests that this process knowledge is lost because the tacit knowledge that the team develops through collaboration (Davenport, 1993) gets redistributed (Fahey and Prusak, 1998). Tacit knowledge is an integral component of knowledge but unlike explicit knowledge, it is difficult to articulate in a way that is meaningful and complete (Nonaka and Konno, 1998). Teece (1998) provides further support to this argument by suggesting that there is correlation between codification of knowledge and the cost of its transfer from one group to another. The larger the extent to which decision and design knowledge has been codified, the lower are its transfer costs between members in a given team and across teams (Teigland et al., 1998).

Unstated assumptions {UA}

Several design decisions made in the process of developing a new product might be based on some technical (Ramesh and Dhar, 1992) or procedural (Bohn, 1994) assumptions made by design team participants. Since team members might be pooled in from different functional specializations, such assumptions might not be apparent to other team members. If such an assumption is made at an early stage in the design process, it may affect later stages of product design. As the number of decisions grow and their corresponding relationships become complex, it becomes difficult to trace the effects of changes in such assumptions on the rest of the design. Court (1997) suggests that the requirements that a product needs to satisfy might change over the period of its development. Iansiti (1997) further strengthens this argument by giving the example of Netscape Corporation's development effort for its early browser (an information product), where the design requirements and underlying assumptions evolved and changed even after the information product development team began building the designed product. Lacking the ability to trace and take into account the effect of a changed assumption on the rest of the design decisions that might have already been made might negatively affect the outcomes of the development effort and in turn success of the product.

In our example of a newspaper's Web news delivery mechanism, participants on the design team who are involved in decision making process come with different assumptions which are brought in from their differing areas of specialization. What might be the most important design factor for an advertising manager (advertisement revenue) might be different from that for an editor (news content density) (Cottrell and Faulkner, 1998) and so forth.

3.4 Characteristics of a System to Support Information Product Development Design Decision-making

The problems identified above pose challenges to an information product development team collaborating on the development of an information product within a distributed space. Tracking the history of design decisions (Robillard, 1999) can help information product designers in accounting for changes in design assumptions and evolving market needs (Shapiro and Varian, 1998). Maintenance of traces for abandoned and interrupted design decisions can help avoid rework (Robillard, 1999). Maintenance of metadata on decisions made in the past can help designers apply and reuse lessons learned from past decisions (Fielding et al., 1998). Our work is based on the premise that if knowledge about the history of design is captured and maintained, it can alleviate many of these problems associated with IPD. The challenge in this research is to represent this historical record in a way that it supports decision-makers involved in the development of an information product.

As our research is geared towards developing decision support systems for this purpose, it is focused on capturing and representing knowledge about the decisions made during IPD process. Recent research recognizes that maintaining knowledge about just the decisions themselves is not sufficient to foster shared understanding of the required decisions among the decision-makers involved in IPD. As much context of such decisions as possible, must also be maintained (Robillard, 1999).

Mapping IPD Problems to System Goals and Characteristics

Recent research on information products proposes several goals for supporting distributed coordination and design decision making of information products (Fielding et al., 1998). In Table 2, we map these goals to IPD problems identified in the previous section and further translate these goals to enabling technology solutions. The first column in Table 2 describes the goals as described by Fielding et al. (1998). The set of information product development problems identified in the preceding section that each goal addresses is represented by its code in the second column. Enabling technologies to support IPD processes are identified in Column 3.

Table 2: Enabling technology for design decision support in distributed collaborative IPD.

Goal (Fielding et al., 1998)	IPD problems addressed	Enabling technology for design decision support
Distributed coordination and design decision making	{SU}, {RS}, {RM}, {IV}	All of the below
Linking artifacts to processes	{LC}, {RM}	Links between process knowledge and artifacts
Flexible interaction model and hypermedia services	{PK}, {UA}	Formal and informal media; hyper-media links
Distributed annotation	{SU}, {RM}	Distributed annotation of artifacts with concept maps
Distributed authoring	{LS}, {IV}	Distributed authoring of process knowledge and concept maps
Visibility of artifacts over time	{LC}, {RS}, {PK}	Recording of design development history / process knowledge

Towards a Mechanism for Supporting IPD Knowledge

We have developed a design decision support system to provide a variety of enabling technologies identified in Table 2. The facilities provided by this system include:

- A WWW based group support environment in which the various participants can conduct deliberations leading to IPD decisions
- Facilities for capturing the context in which these decisions are made. Using a distributed multimedia annotation system, the decisions and the rationale for these decisions can be linked to the artifacts, supporting documents and other related information on the WWW.
- A facility to manage the complex network of dependencies among the various components of knowledge often thinly spread across the various participants in collaborative teams.
- A facility for intelligent retrieval of components of design decision knowledge based on ad-hoc requirements of the various participants.
- A mechanism to maintain the consistency of the captured knowledge so that the knowledge is current and accurate

Linking Artifacts to Processes

Kline et al. (1998) stress the importance of integrating tools for supporting collaborative work within the context of the work environment. We provide a variety of support mechanisms to address this issue: We recognize the importance of relating process knowledge to the artifacts that are outcome of the processes. We provide a model for capturing deliberations in which components of process knowledge (such as requirements, assumptions, decisions, assumptions etc.) can be captured For example, the conversations may be conducted using REMAP, a model based on the IBIS argumentation model (Ramesh and Dhar, 1992). Using our tool, the users can not only capture details of the deliberations, but also maintain links to the artifacts that are the "inputs" and "outputs" of these deliberations. For example, the components of a deliberation on the production different versions of a CD-ROM IPD can have embedded in them, links to the actual code (represented in the HTML format). Similarly, a link embedded in the artifacts can be used to retrieve a discussion related to its creation and maintenance as shown in Figure 1.

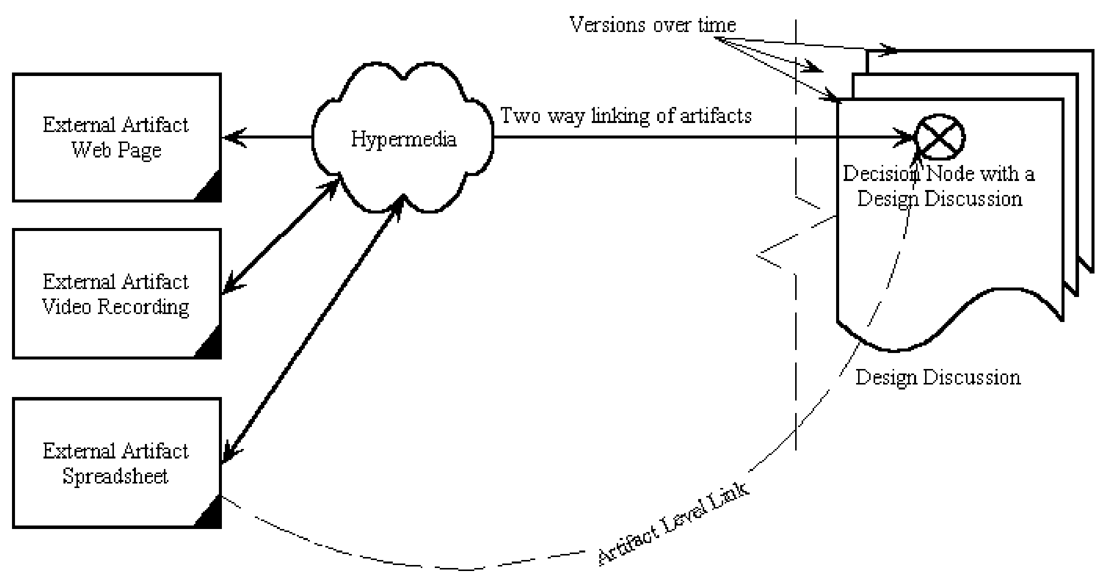


Figure 1: Linking artifacts to processes

Flexible Interaction Model and Hypermedia Services

Design history can be represented in varying degrees of formality. Formal representations can help automated reasoning, but are difficult to develop in most complex, dynamic design situations.. Whereas informal descriptions help create thick descriptions, indexing, retrieval and formal reasoning with such information can be difficult. We provide the flexibility to represent process knowledge in a variety of forms ranging from formal specifications to hypermedia objects. For example, the belief in an assumption can be represented formally, whereas, the video /audio clips of discussions involving demonstrations of various versions of the IP can be represented using hypermedia.

Depending on the complexity and importance of a decision, the rationale behind it may be captured at different degrees of detail. Our system provides the flexibility to represent decision rationale at different levels of granularity or detail. In the simple view, the users can annotate their decisions with notes and assumptions. In the detailed view, however, they can create a complex network of requirements, issues, alternatives, arguments and assumptions that were critical in arriving at a decision.

Distributed Annotation

Boland and Tenkasi (1995) argue that it is essential to support explicit representations for exchange of views and undertakings among distributed team members. We support explicit representation of ideas and viewpoints using concept maps. These maps can be used by the participants to create detailed representation of the variables and assumptions used by them in defining problem and solution spaces. In complex situations the team members may use different variables to describe the problem and solution spaces. Further, different members of a team may use the same term with different meanings. The concept maps representing such information can be thought of as annotations (Boland and Tenkasi, 1995) explaining the viewpoints of individual participants that contributed to the development of the information product. Consider the scenario in which an editorial staff member proposes a layout of the WWW version of a newspaper that prominently places an editorial segment. This team member may explain the philosophy behind his design by clearly identifying the variables s/he considers important in prioritizing various segments to be accommodated in the newspaper. This ability to link knowledge about the problems and solutions to the artifacts can be used by the various team members to created distributed annotations on the information products developed collaboratively.

Distributed Authorship

Our tool is based on a client server architecture in which clients may be distributed over local or wide area networks. The clients connect to a centralized knowledge base to retrieve, define and modify components of process knowledge and concept maps. This architecture supports distributed authoring by team members.

Visibility of Artifacts over Time

A major concern with the development of information products is loss of knowledge about the history of the evolution of information products over time, which leads to many of the problems discussed in section 3. For example, the current layout of an online newspaper can be best understood only if the previous versions of the layout as well as the reasons behind the changes made to the prior versions that led to the current version are readily available. Our system provides the facilities to capture this information about the history of evolution. By capturing the various issues considered, the alternative solutions proposed, the arguments supporting and opposing each of these alternatives and the assumptions behind each of these, the designers can explicitly articulate the rationale behind the evolution of their artifacts over time.

In the following section we describe the functionalities of the DSS.

4. Design Decision Support System

Our DSS provides facilities for defining, browsing and modifying knowledge about history of development of information products. We illustrate the capabilities of the system using scenarios on the development of various versions of an online newspaper.

4.1 Linking Process to Artifacts

Consider the situation in which a team of developers is involved in designing the layout of the newspaper. Several participants contribute to this important decision. They range from the editors in charge of the various sections such as sports, business, technology etc. as well as functional areas such as marketing that is responsible for the sale of the paper and advertising that is responsible for generating advertisement revenues. The discussions among these team members may be conducted using our tool. Figure 2 shows the results of such a discussion. The discussion centers on the requirements for designing the front page of the layout. Varieties of concerns or issues that are raised by the team members include the following:

- Does information about weather belong in the front page?
- Does information on sports scores belong in the front page?

Each of these issues in turn may lead to more specific questions such as where in the front page will the weather information be? How much space should be allocated in the front page for the weather information? etc. The team members involved in the weather section may propose alternative solutions. For example, a team member suggests that this segment belongs in the banner based on the argument that it will provide high visibility. This argument is based on the assumption that the target audience desires such a high visibility placement of weather. Similarly, other team members propose different alternatives. They also support and/or oppose the various alternatives. Figure 2 also shows a fragment of a discussion on the placement of sports scores. Each of the proposed alternatives has a direct effect on the final layout to be chosen. Based on the evaluation of the various alternatives (to be discussed in more detail below) the team makes a decision to choose one of the alternatives. Our tool provides the ability to hyperlink this decision to the corresponding layout design. Thus, the rich history behind the choice of the layout is captured in detail and linked to the artifact itself.

4.2 Flexible Representation and Hypermedia

In the above scenario, the representation of history behind design decisions was guided using the primitives of an extended Issue Based Information System model (Conklin and Begeman, 1988; Ramesh and Dhar, 1992). However, the tool provides the flexibility to customize the representation in a number of ways. First, a different conversation protocol may be used simply by changing the schema that represents the nodes and links in the model of collaboration. Second, we recognize that a team may wish to represent the history behind decisions at varying levels of detail or granularity. The discussion in Figure 2 represents a very detailed model (see Appendix 2 for a legend). Instead, the users may switch to a simple model in which only the decision and the assumptions may be recorded. By providing this flexibility, the tool enables the capture of history at the desired level of detail. Two-way linking between the artifacts and the design history is provided by the ability to embed the reference to any specific discussion within any hypermedia document. For example, various segments of a layout represented in the hypermedia format may have references to the discussions corresponding to that choice. A user can therefore seamlessly move from the discussion to the artifact and vice versa.

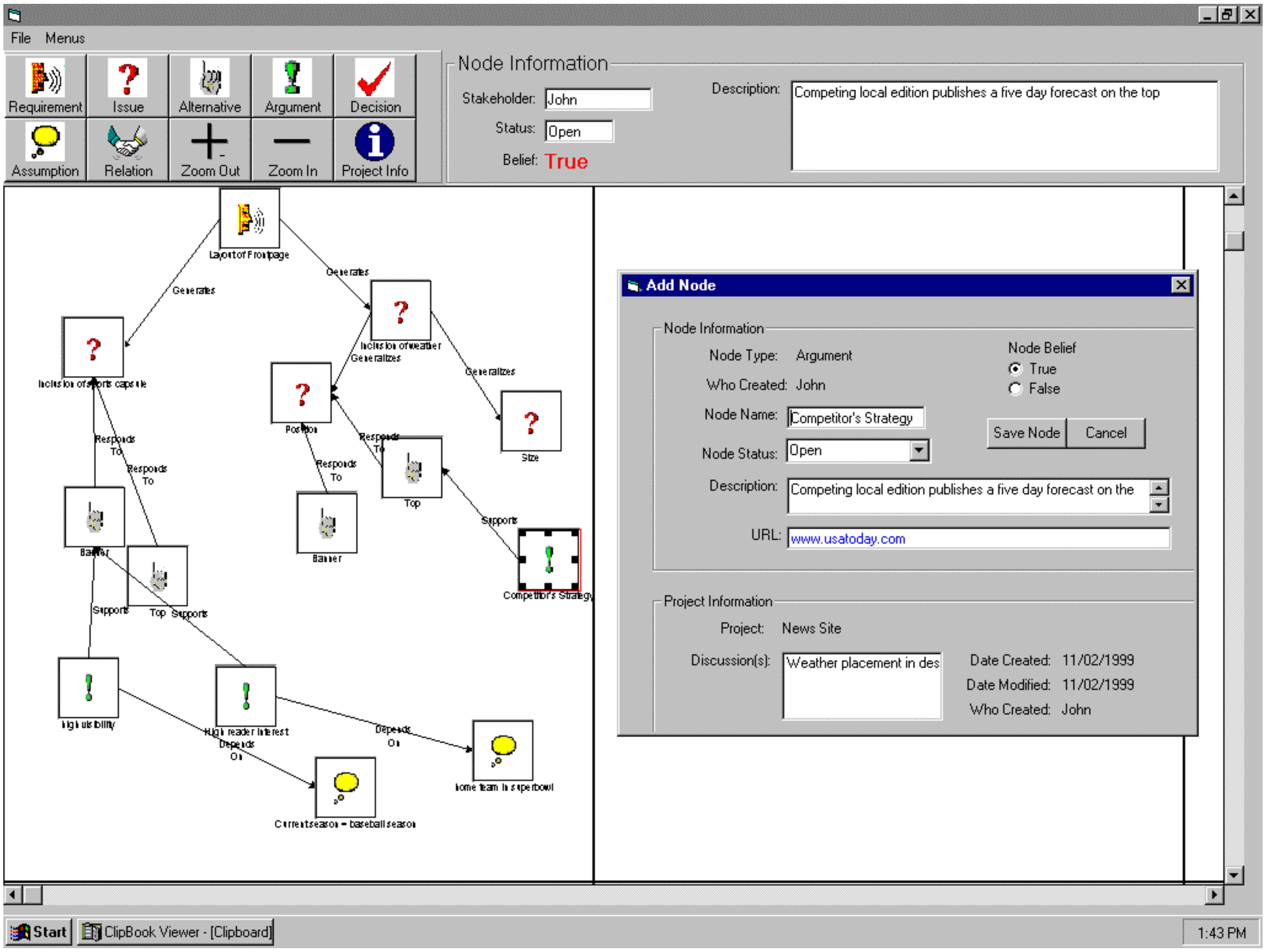


Figure 2: A design decision discussion with two way links between artifacts.

The need to represent the context in which decision are made is supported in our model by the ability to hyperlink any node in the model to hypermedia documents. For example, the alternative to use a weather strip at the bottom of the page may be supported by the argument that it is the format employed by a competing publication. A hyperlink to that publication may be created to completely capture the context in which this argument was made (see Add Node insert in Figure 2).

4.3 Distributed Annotation

The tool supports distributed annotation with concept maps. Again, the concepts to be used to help communicate different viewpoints may be specified by the team members. For example, a team may use decision variables as the concept of interest. Each member of the team involved in layout design may describe the various variables that they consider as important in arriving at a layout. Marketing and Advertising may be interested in attractive design and potential for increased advertising revenues respectively as their top priorities. The other team members may seek clarifications on these concepts to fully understand the respective viewpoints. Marketing may elaborate on its choice to mean the use of color and rich media as enhancing the attractiveness of the design. Similarly, other team members may use this facility to specify their choices and elaborate on them. This ability to exchange viewpoints enhances the chances for shared understanding among team members, which is essential for successful collaboration.

4.4 Distributed Authoring

Our prototype DSS supports distributed development of information products with a client server architecture. The clients can be invoked from a Web browser. The team members using the client interface can connect to a central knowledge server that maintains process knowledge components. This facilitates distributed authoring of design history and concept maps by the team members.

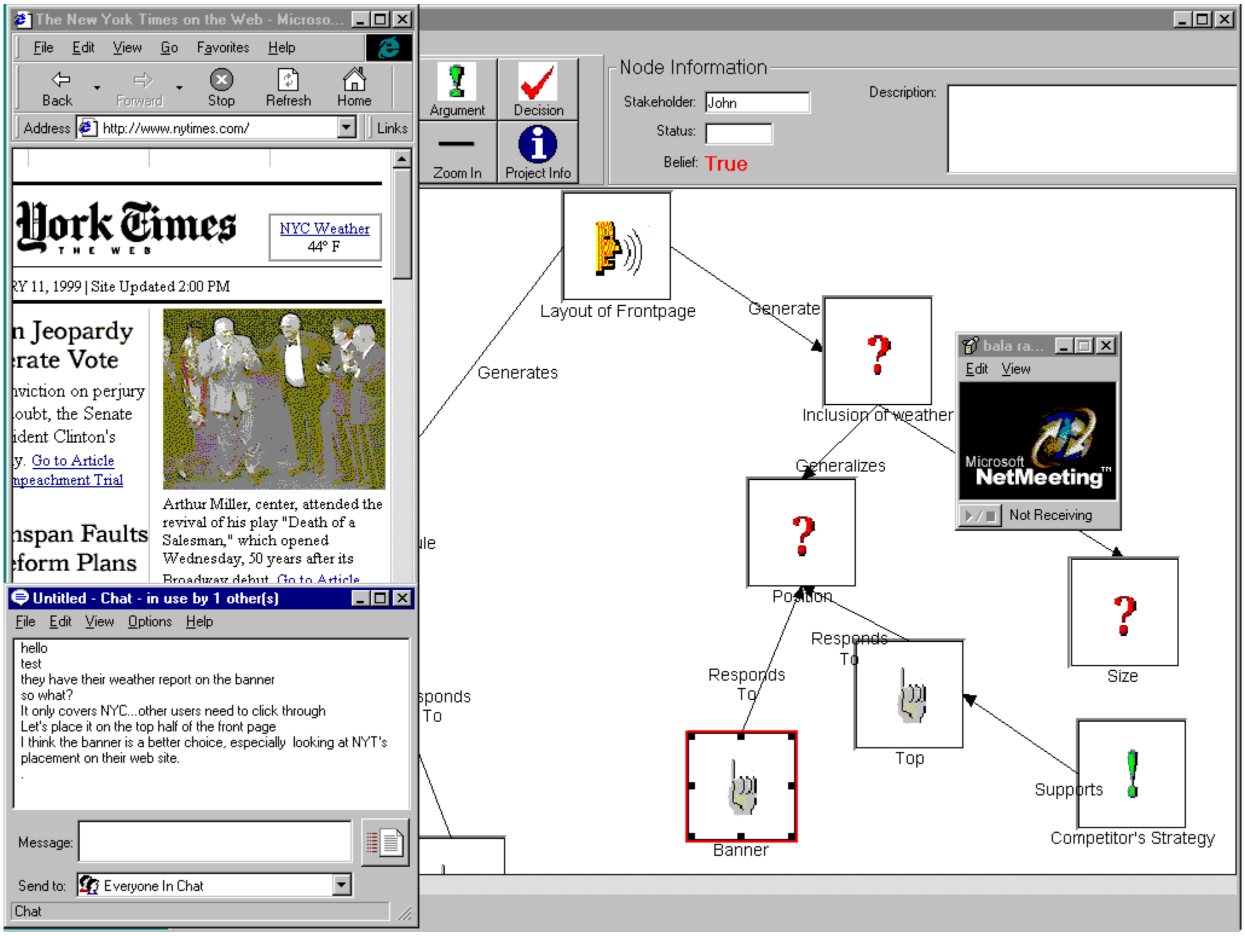


Figure 3: Distributed authoring, links to external knowledge sources(in this case, a competitor's site) and relevant real time deliberations can be captured and linked to design decisions as they are made

Figure 3 illustrates the use of the DSS in conjunction with Netmeeting, a collaboration support environment. The IPD team is engaged in the discussion on the position of the weather segment in the front page using the chat utility. A team member who suggests positioning weather in the banner, shares a Web browser that displays the competitor's design. Our system complements Netmeeting's ability to support conversations and share applications in a number of ways. The essential aspects of unstructured conversations conducted within Netmeeting, can be captured within our tool in a semi-structured format. Segments of the conversations can be directly imported into the nodes in our network of design history. Further, the artifacts themselves can be two-way linked to the contents of the conversations. As mentioned earlier, the competitor's Web page can be linked to the argument and the decision to the layout that displays weather in the intended position.

4.5 Decision Support with Visibility of Artifacts over Time

Our tool provides a variety of decision support aids to not only capture knowledge about the history of development, but also to maintain the consistency of such knowledge and perform automated decision support with that knowledge, especially when the context in which the decisions are made change. Recall that the validity of the alternatives proposed also depends on the validity of the assumptions behind these alternatives. Simon (1991) suggests that all stakeholders involved in the delivery of a product must be involved from its inception. He gives an example of manufacturing industries where the failure to consider manufacturability at an early stage usually causes extensive redesign with a product, thereby causing major delays in production and subsequent delivery (Simon, 1991). For example, the suggestion to use the banner for weather is based on the assumption that such a high visibility placement is desired by the customer market segment.

The marketing department may be asked to evaluate this assumption. If they invalidate this assumption, then the system propagates the effects of this assertion to invalidate the decision. Similarly, the evaluation of the assumption about the current interest in the sports segment may lead to the validation of the alternative to use the banner for sports scores. This ability to dynamically synthesize the layout based on process knowledge can be very valuable in a variety of ways. For example, two editions of the same paper produced in different cities may be composed with different layouts based on their specific conditions (whereas sports may be at the top priority for a city in Southern California hosting a sporting event, weather may be most appropriate for a city in the north east facing a major storm). First, the system helps synthesize these designs based on a common and consistent set of design principles discussed by the team members. Second, when the context in which the decisions are made changes (which is common in the development of information products like an online newspaper where new stories of high importance may develop at any time), the system helps rapidly identify components of the design that are valid. Finally, the history of the development of the information product is captured in its complete form so that the teams will have access to this information when designing other versions of the product. Our system supports ad-hoc queries to retrieve components of this history to support decision making. For example, a design team may want to review what the layout looked like when similar conditions existed in the past and more importantly, why so? The ability to access and reuse such information will be extremely valuable.

5 Related Work

Many tools for capturing design rationale proposed in the literature use argumentation models such as issue based information systems (Conklin and Begeman, 1988). Tools such as (Conklin and Begeman, 1988) and IBE (Lease et al., 1990) provide only passive support for the capture of rationale. In contrast, we advocate active support for both capture and use of history. Our work is similar in spirit to that of the SYBYL project (Lee, 1990) in providing automated reasoning tools. Our work extends this support further by providing mechanism for distributed coordination with annotation and authoring, as well as providing links between artifacts and design history.The need for hypermedia annotation of artifacts has been suggested by prior research (Bhargava et al., 1994). Our approach extends such proposals by documenting detailed design history in a semi-structured way so that automated support for the use of this information can be provided. This research differs from earlier work on the capture of semi-structured history information exemplified by tools that support IBIS and its extensions (Conklin and Begeman, 1988; Ramesh and Dhar, 1992) in its focus on providing a tight integration between the process knowledge and the artifacts themselves. In the domain of information product development, the tight integration between the process knowledge components and artifacts themselves can be maintained. The synthesis of a design solution can readily be supported when the context for the design decisions change. Thus, whereas the focus of decision support in the current research is the *synthesis* of information products, prior research has concentrated on providing access to history to help design teams working in the later phases of a project or a future project. The scope for opportunistic planning and synthesis are high in IPD (Robillard, 1999) and our decision support tools are geared towards supporting these activities. Recent studies on the use of structured argumentation techniques to capture organizational memories suggests that complex models are appropriate for some “wicked” problems whereas simpler schemes are more appropriate for other contexts (Shum, 1998). This finding supports our approach of supporting the capture and use of history at multiple levels of abstraction or detail. Though the WWW has emerged as an important medium for the production and delivery of information products, the current WWW infrastructure has several missing elements for the development of annotation systems (Vasudevan and Palmer, 1999). We have proposed an annotation system that complements the capabilities currently available on the WWW.

6 Discussion

The capture of knowledge about the history of development can be very expensive. However, studies in the domain of software engineering (such as (Yakemovic and Conklin, 1990)) document the feasibility and usefulness of such efforts even in large-scale projects. Even in domains where the tight integration of design process knowledge and the artifacts can not be easily maintained, the benefits of maintaining comprehensive design history have been observed (Ramesh and Sengupta, 1995). Due to the tight integration between process knowledge and the information products themselves, the benefits of design history information can be significantly higher. Bellanger et al. (1997) note that such a process oriented approach to publishing is generalizable to a certain level of granularity for all companies developing such products. While our example discussed a scenario involving layout and content issues in the development of information products, it can also be applied to other IPD processes such as color configuration in the product planning stages, "repurposing" components of an information product and distribution (Bellander et al., 1997). However, detailed empirical studies crucial to establish the effectiveness of the approach proposed here are the subject of ongoing research.

The overhead involved in the capture of history can be significantly reduced if the information can be captured in a non-intrusive manner. We are currently investigating the use of concept classification techniques to identify components of this knowledge from chat and e-mail exchanges.

References

Ballou, Wang, Pazer and Tayi, "Modeling Information Manufacturing systems to Determine Information Product Quality", Management Science, 44 (4), 462-484, 1998.

M. Bellander, "Workflow Bottlenecks and Problem Areas Influencing Production Management Needs in Commercial Printing", in: Proceedings of the Intergrafica, Zagreb, Croatia, November,

M. Bellander, L. Handberg and J. Stenberg, "Workflow Analyses in Commercial Printing - Methods and Results", in: Proceedings of the IARIGAI, London, England, September 8-9, 14.

H. Bhargava, R. Krishnan and A. Whinston, "On Integrating Collaboration and Decision Technologies", Journal of Organizational Computing, 3 (4), 297-317, 1994.

R.E. Bohn, "Measuring and Managing Technological Knowledge", Sloan Management Review, 36 (Fall), 61-73, 1994.

R. Boland and R. Tenkasi, "Perspective Making and Perspective Taking in Communities of Knowing", Organization Science, 6 (4), 1995.

A. Chang and M.E. Jackson, "Managing resource sharing in the electronic age" AMS Press, New York, 1996.

C. Ciborra, "Teams, markets, and systems : business innovation and information technology" Cambridge University Press, Cambridge [England] ; New York, 1993.

K.B. Clark and S.C. Wheelwright, "The product development challenge : competing through speed, quality, and creativity" Harvard Business School Press, Boston, 1994.

J. Conklin and M. Begeman, "gIBIS: A hypertext tool for exploratory policy discussion", ACM Transactions on Office Information Systems, 6 303-331, 1988.

L. Cottrell and A. Faulkner, "Print Publishing Guide" Adobe Press, San Francisco, 1998.

A.W. Court, "The Relationship Between Information & Personal Knowledge in New Product Development", International Journal of Information Management, 17 (2), 123-138, 1997.

E.Y. Cross and M.B. White, "The diversity factor : capturing the competitive advantage of a changing workforce" Irwin Professional Pub., Chicago, 1996.

Davenport, Jarvenpaa and Beers, "Improving Knowledge Work Processes", Sloan Management Review, (Summer), 53-65, 1996.

T.H. Davenport, "Process innovation : reengineering work through information technology" Harvard Business School Press, Boston, 1993.

T.H. Davenport and L. Prusak, "Working knowledge : how organizations manage what they know" Harvard Business School Press, Boston, 1998.

W.H. Davidow and M.S. Malone, "The virtual corporation : structuring and revitalizing the corporation for the 21st century" HarperBusiness, New York, 1992.

P.M. Dillon, "The quest for knowledge management : a new service organization to address the challenges & opportunities" Information Management Forum, [Atlanta, Ga.], 1997.

R.J. Dolan, "Managing the new product development process : cases and notes" Addison-Wesley, Reading, Mass., 1993.

P. Drucker, "Post Capitalist Society" Harper Business Press, New York, NY, 1993.

L. Fahey and L. Prusak, "The eleven deadliest sins of knowledge management", California Management Review, 40 (3), 265-276, 1998.

S.A. Faraj, "Coordinating expertise in software development teams" 1998.

Fielding, Whitehead and Anderson, "Web Based Development of Complex Information Products", Communications of the ACM, 41 (8), 84-92, 1998.

Fuller, C. and D.Russel, A design rationale capture using Remap/MM, Master's thesis, nabal Postgraduate School, 1994.

M. Iansiti and A. MacCormack, "Developing Products on Internet Time", Harvard Business Review, (September-October), 108-117, 1997.

A. Inkpen, "Creating knowledge through collaboration", California Management Review, 39 (1), 123-140, 1996.

A.R. Jassawalla and H.C. Sashittal, "An examination of Colloboration in High Technology New Product Development Process", Journal of Product Innovation Management, (15), 237-254, 1998.

Koppius, "Dimensions of Intangible Goods", in: Proceedings of the 32nd Hawaii Internatioinal Conference on system Sciences, Maui, Hawaii, January 1999,

M. Lease, M. Lively and J. Leggett, "Using an Issue Based Hypermedia System to Capture the Software Life Cycle Process", Hypermedia, 2 (1), 1990.

J. Lee, "Sybil: A Qualitative Decision Management System", in: Whinston and Shellard, Eds., Sybil: A Qualitative Decision Management System, MIT Press, Cambridge, MA, 1990,

D. Leonard and S. Sensiper, "The Role of Tacit knowledge in Group Innovation", California Management Review, 40 (3), 112-131, 1998.

D. Leonard-Barton and S. Sensiper, "The Role of Tacit knowledge in Group Innovation", California Management Review, 40 (3), 112-131, 1998.

Malone, Yates and Benjamin, "Electronic Markets and Electionic Hierarchies", Communications of the ACM, 30 (6), 484-497, 1987.

D. Mankin, S. Cohen and T. Bikson, "Teams and Technology" Harvard Business School Press, Boston, Massachusetts, 1996.

J.G. March, "Exploration and Exploitation in Organizational Learning", Organization Science, 2 (1), 71-87, 1991.

J.G. March, "The pursuit of organizational intelligence" Blackwell, Malden, Ma, 1999.

M. Meyer and M. Zack, "The Design & Development of Information Products", Sloan Management Review, 37 (3), 43-59, 1996.

Mullins and Sutherland, "New Product Development in Rapidly changing Markets: An exploratory Study", Journal of Product Innovation Management, (15), 224-236, 1998.

Nonaka, Reinmoeller and Senoo, "The ART of Knowledge: Systems to Capitalize on Market Knowledge", European Management Journal, 16 (6), 673-684, 1998.

I. Nonaka, "Managing innovation self-renewing process" J Bus Venturing 4 299-315 (1989), 1989.

I. Nonaka and N. Konno, "The Concept of "Ba": Building a foundation for Knowledge Creation", California Management Review, 40 (3), 40-55, 1998.

I. Nonaka and H. Takeuchi, "The knowledge-creating company: how Japanese companies create the dynamics of innovation" Oxford University Press, New York, 1995.

Powell, "Learning from collaboration", Sloan Management Review, 30 (3: Spring), 228-239, 1998.

B. Powell, "Knowledge of actions" Humanities Press, New York, 1967.

J.B. Quinn, P. Anderson and S. Finkelstein, "Managing Professional Intellect: Making the Most of the Best", Harvard Business Review, March-April, 1996, 71-80.

J.B. Quinn, J.J. Baruch and K.A. Zien, "Innovation explosion : using intellect and software to revolutionize growth strategies" Free Press, New York, 1997.

B. Ramesh and V. Dhar, "Suppporting Systems Development using Knowledge Captured during Requirements Engineering", IEEE Transactions on Software Engineering, 1992.

B. Ramesh and K. Sengupta, "Multimedia in a Design Rationale Decision Support System", Decision Support Systems, 15 181-196, 1995.

B. Ramesh and A. Tiwana, "*Supporting Collaborative Process Knowledge Management in new product development teams*", Decision Support Systems, Forthcoming 38, 1999.

Robillard, "The Role of Knowledge in Software Development", Communications of the ACM, 42 (1), 87-92, 1999.

R. Sanchez and A. Heene, "Strategic learning and knowledge management" Wiley, Chichester New York, 1997.

C. Shapiro and H. Varian, "Versioning: The Smart way to Sell Information", Harvard Business Review, (November-December), 16-114, 1998.

C. Shapiro and H. Varian, "Information Rules: A Strategic Guide to the Network Economy" Harvard Business School Press, Boston, MA, 1999.

S. Shum, "Negotiating the Construction of Organizational Memories", in: U. Borghoff and R. Pareschi, Eds., Negotiating the Construction of Organizational Memories, Springer, New York, 1998.

H.A. Simon, "Bounded Rationality and Organizational Learning", Organization Science, 2 (1), 125-134, 1991.

M. Song and M. Montoya-Weiss, "Critical Development Activities for Really New versus Incremental Products", Journal of Product Innovation Management, 15 124-135, 1998.

Techart, "Digital prepress book for Macintosh power user designers" TechArt Japan, Tokyo, Japan, 1993.

D. Teece, "Research directions for knowledge management", California Management Review, 40 (3), 289-292, 1998.

R.E. Teigland, C. Fey and J. Birkinshaw, "Knowledge Dissemination in Global R&D Operations: Case studies in three multinationals in the high technology electronics industry.", Stockholm School of Economics, Stolkholm (1998).

A. Tiwana and A. Raven, "Extending the Product Platform Architecture Approach to Enhance Knowledge Transfer in Information Product Development", in: Proceedings of the Southern Association for Information Systems (SAIS-99), Atlanta, GA, 21-24 April,

D. Tjosvold and M.M. Tjosvold, "Leading the team organization : how to create an enduring competitive advantage" Maxwell Macmillan International, New York, 1991.

V. Vasudevan and M. Palmer, "On Web Annotations: Promises and Pitfalls of Current Web Infrastructure", in: Proceedings of the HICSS-32, Maui, Hawaii,

A. Webber, "What's So New about the Economy", Harvard Business Review, (January-February), 4-11, 1993.

M. Webster, Merriam Webster Dictionary on the Web http://www.m-w.com/cgi-bin/netdict, . 1999.

W. Wong, "Management guide to software reuse" Nbs, Gaithersburg, MD, 1988.

K.B. Yakemovic and E.J. Conklin, "Report on a Development Project Use of Issue Based Information System", in: Proceedings of the Computer Supported Cooperative work, 105-118.

K.P. Yglesias, "Information reuse parallels software reuse", IBM Systems Journal, 32 (4), 615-620, 1993.

Zack, "An Architecture for Managing Explicated Knowledge", Sloan Management Review, Forthcoming 1999.

Appendix 1: Additional Examples (Case studies reproduced from Fuller and Russel, 1994).

1. USE OF REMAP IN REQUIREMENTS ENGINEERING

During the requirement phase of a project, detailed knowledge of the background and history of the system is required in order to make sound decisions concerning the system's design requirements. For example, when a system designer is building a new user interface, s/he should have a deep understanding of how the interface would be used, and what the potential users will need to effectively perform their jobs. This portion of the example illustrates how REMAP could be used during the requirements phase to effectively capture this essential background information.

1. Background Information

When the power company first began providing power, its clients were located in the downtown Jacksonville area. As the city grew and expanded, outlying cities such as Jacksonville Beach, Neptune Beach, and Orange Park were incorporated into the company's power grid, making Jacksonville the largest geographical city in the United States. Today, the city has expanded to include all of Duval County, an area of nearly 840 square miles. The city has experienced a population growth rate of nearly 28 percent in the past ten years, and power demands have increased at a similar rate.

To improve the service to this expanding city while dealing with company-wide downsizing, the power company has determined that an automated service order processing system is the most economical solution. This new system must provide a more efficient means of handling calls from the customer for maintenance and emergency service, and allow the company to dispatch troubleshooters in the most effective manner.

Presently, the power company operates four regional centers. Each center consists of 3-5 phone Service Operators who answer calls from within their service area. These operators provide the customer with a variety of services, arrange electrical service start or stop dates, answer any billing question the customer might have, as well as take any trouble call information from the customer and forward the information to the service dispatcher. The Service Dispatcher prioritizes daily work schedules, assigns jobs to field units, and monitors the progress of all field workers. The field workers have to coordinate there work with the distribution operator. The Distribution Operator coordinates all field maintenance from a central location.

The new system must allow the company to expediently dispatch their limited number of linesmen more effectively. When a service call comes into the center, a Multipurpose Customer Service Order or service tag is generated. This tag contains all relevant information about the customer service request. When there is a large-scale power outage, thousands of these tags can be generated. In order to dispatch the limited number of troubleshooters to the most likely source of the outage, the tags must first be manually sorted by geographic area. Once these tags are sorted, they must then be cross-referenced with a power Grid map according to substation and feeder lines . From this map, a more precise localization of where the trouble is can be determined. Since this is all performed manually, it can typically take several hours to localize and dispatch troubleshooters to the proper area.

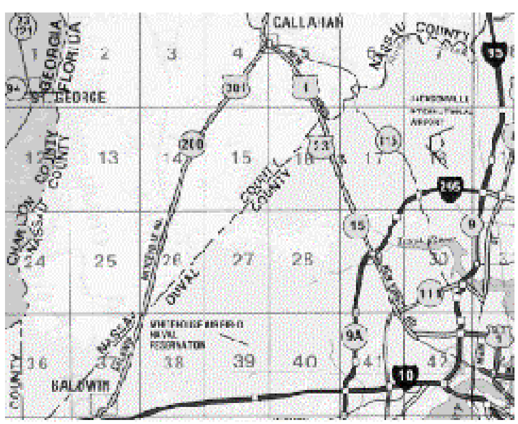
With the Current Switching Method, switches must be manually opened and tested to determine if they are indeed the trouble spot, or the problem exists somewhere else along the line. Once the exact location of the trouble has been determined, the troubleshooters can begin working on the solution to the problem. With the current system, it is not uncommon for 15-24 hours to pass before power can be restored. With the installation of the Intelligent Switches And Fuses, the power company's goal is to completely automate the service system. Each client's address will be linked to a particular fuse or switch, allowing the computer to expediently localize the trouble spot. The intelligent switches and fuses will allow for some of the repair work to be completed remotely. The distribution operator needs simply to switch the intelligent switch on or off over the phone. This will allow for more expedient troubleshooting before having to dispatch workers to the field. This new system must provide a more efficient means of handling the processing of customer maintenance request status. Once the troubleshooters are on site, they must assess the situation and notify the regional center of the estimated time that will be required to fix the problem. This information is currently first passed to the dispatcher from the linesmen. From there it is forwarded to the service center operators, time permitting, where it is then posted on a chalkboard so the operators can inform calling customers of the estimated time until their service is restored. The linesmen then coordinate with the distribution operator to ensure that they can safely perform the maintenance without endangering other workers or themselves.

Finally, after the work has been completed, every person who called in must be contacted to determine if their power has been restored. If their power is not back on, the entire process must be repeated.

2. Service Operators

Presently, the power company operates four regional centers. The four regional service centers are divided geographically.

Region One: North of I-10, West of I-95:



Region Two, Region Three, Region Four. Each center consists of 3-5 phone operators who answer calls from within their service area. These operators provide the customer with a variety of services, arrange electrical service start or stop dates, answer any billing question the customer might have, as well as take any trouble call information from the customer and forward the information to the service dispatcher.

3. Service Dispatcher

The service dispatcher plays a vital role within the maintenance system of the power company. Due to the extremely large geographic area, that the company serves, a great deal of coordination and prioritizing must take place to ensure that service is maintained and restored to as many people as possible in the shortest amount of time. In accomplishing this goal, the service dispatcher must prioritize daily work schedules, assign jobs to field units, and monitor the progress of all field workers. Additionally, during the evening hours, the service dispatcher becomes the only service operator on duty, increasing the amount of coordination required.

4. Distribution Operator

The distribution operator is one of the key safety coordinators for all maintenance actions. When a field worker needs to perform maintenance on a particular section of line, the distribution operator ensures that the maintenance is performed safely. The operator does this by referencing a checklist of maintenance steps while the field worker is performing the maintenance. While doing this, s/he must also make sure that the power to the effected line is secured, and that it is safe for the field worker to proceed.

5. Grid

What is commonly referred to as the "grid" is in fact the layout of all the electrical lines throughout the city.

The power grid is made up of substations, lines, circuit breakers, switches and fuses. This grid is in turn laid over a map of the geographic area, allowing for isolation of individual residences or businesses that may be experiencing problems.

6. Switches and Fuses

Substations are the sources for the power that goes out on a particular line. The line, typically 21,000 volts, carries the power throughout the area for distribution. Smaller, 1000 volt lines fe1ed off of the 21 kilovolt lines and step down to distribute electricity to individual residences and business. On each of these high and low power lines are circuit breakers, switches, and fuses. These devices protect the equipment from surges and underages of power, which can cause damage to vital equipment.

7. Current Switching Method

During a global, large-scale outage, workers must progressively switch on and off the switches within the system in order to isolate where the problem is located. Once the problem has been located, only then may work proceed in order to restore service. This is typically a very time consuming endeavor, requiring a great deal of coordination and manpower. When work or maintenance needs to be performed on a particular line, a field worker must go out to the circuit breakers, switches, or fuses directly upstream and downstream from the affected piece of equipment, and manually switch them off to isolate the line. Once this has been accomplished, then work on that line or piece of equipment may proceed.(Return to background information)

8. Intelligent Switches and Fuses

The company has begun to replace its old technology switches and fuses with new, "intelligent" switches and fuses. These new devices can be controlled via the telephone, automatically switching on or off when receiving the appropriate code. These switches are denoted on the power grid map with the "TC" code, which means telephone controlled.

3.2. USING REMAP DURING SYSTEM ANALYSIS

The following section of the example illustrates REMAP's use during the system analysis phase. In the scenario, the analysts are engaged in a deliberation on a requirement for processing service orders. Three issues that are raised by the team members are:

How should calls be handled?

How are service orders prioritized?

How are service orders tracked?

The deliberation involves verifying alternatives or alternatives that solve the issues and arguments behind them, and their underlying assumptions. We briefly describe how various multimedia segments of the discussion are incorporated in the design rationale knowledge.

1. Process Service Order Information

A primary requirement is that the system should be able to handle incoming calls, establish priorities among the calls, and track the calls once they have been answered. Many customers require up to date and accurate information in order to make important, sometimes life or death, decisions. For example, a residential customer may be reliant on an electrically operated medical device. She could not survive for more than five hours without this device. This customer needs to know when the power will be restored, so a decision can be made as to whether or not to move to a location where electricity is still available.

a. How Should Calls Be Handled? (Issue) (Please see the figure below.)

The primary interface between the company and the customer is through service calls. Meeting the needs of the customer is the company's main goal, and achieving this can best be accomplished by effectively and efficiently handling incoming calls. The issue of importance here is how to handle incoming calls.

i. Human Operator (alternative)

The first alternative is that the calls should all be handled by a human operator, who will take information and route the call manually.

ii. Personal Interaction (Argument)

The operator is the only person that the customer will interact with. All of the customer's perceptions about the company are based on their experiences with the phone operators. For this reason, human operators are preferable to automated systems. Computer systems cannot provide the personal touch that customers prefer.

iii. Current Answering Methods (Argument)

The current system of call handling is operator interaction with the customer. An automated system would add costs to the established system, and would degrade the company's public image both among its employees and the general public.

iv. Computer Routing (alternative)

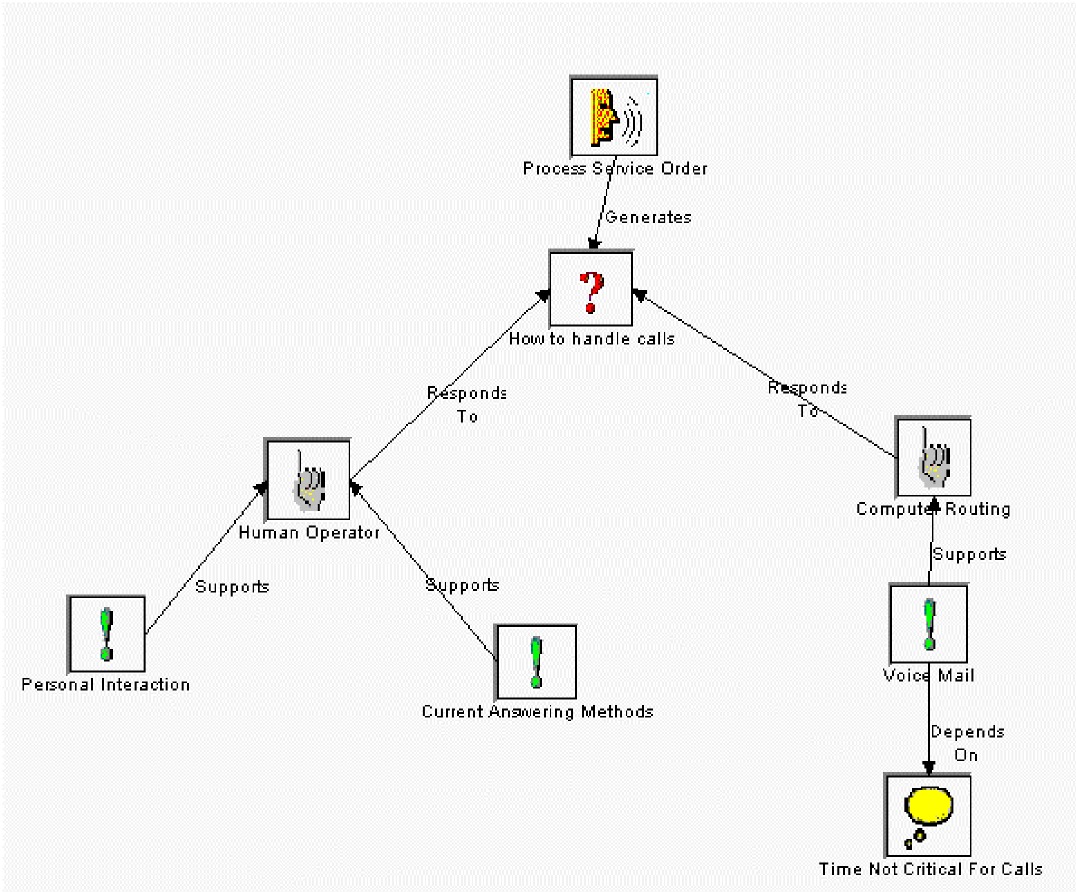
Computer routing allows the customer to indicated what type of service is required before having to talk with an operator.

v. Voice Mail (Argument)

A voice mail system would allow the customer to leave a message indicating what type of service is required, allowing the operators to handle more urgent calls directly.

vi. Time Not Critical For Calls (Assumption)

Most calls that come in to the service center are not of a critical nature. By using a computer routing system that breaks out calls by their type (billing, maintenance, service, etc.), operators will be able to spend more time handling critical calls.


Process Service Order
Generates
How to handle calls
Responds To
Responds To
Human Operator
Computer Routing
Supports
Supports
Supports
Personal Interaction
Current Answering Methods
Voice Mail
Depends On
Time Not Critical For Calls

b. How frequently should orders be processed (issue), and How they are to be prioritized (issue)?

i. Process Order (Requirement)

The utility is considering the requirement to process service orders placed by its customers for various kinds of services. This requirement raises the above two issues .

The issue of prioritizing orders is very critical to meeting a variety of objectives related to processing orders and is considered to be worthy of a serious discussion. Three alternative ways of prioritizing orders is discussed by the design team.

ii. Location (alternative)

One suggestion is to pull together all orders that are from a given geographical location or area.

iii. Economical (argument)

The above alternative is supported by the argument that grouping orders originating from the various areas serviced by the company is the most economical way to process orders.

i.v. Large service area (assumption)

The above argument is based on the assumption that the company is servicing a very large geographical area and therefore, its needs can not afford to dispatch multiple teams to diverse locations within cost and time constraints.

v. Customer type (alternative)

The second alternative proposed by a member of the design team is that orders can be prioritized based on the type of customer being serviced. For example, all requests originating from hospitals will be treated with higher urgency compared to those coming from residential customers.

vi. Prompt service (argument)

The above alternative is supported by the argument that it is essential to provide prompt service to certain types of customers (e.g., hospitals, industrial customers with power critical processes). This argument is based on two underlying assumptions.

vii. Versatile crew (assumption)

One critical assumption is that the company employs a crew that is trained to handle all kinds of requests that may originate from the various customer segments.

viii. Similar needs for all customers (assumption)

The argument will also depend on the assumption that all customers (within a customer segment like residential customers) have similar needs. For example, if some residential customers also have life-saving medical equipment then treating them as other residential customers will be disastrous (i.e., will make this assumption untrue).

ix. Service type (alternative)

The third alternative proposed by the design team is to combine all orders for a specific service (i.e., outages, turning off service etc.).

x. Easy processing (argument)

The above alternative is supported by the argument that it is the easiest way to process customer orders.

xi. High processing time (assumption)

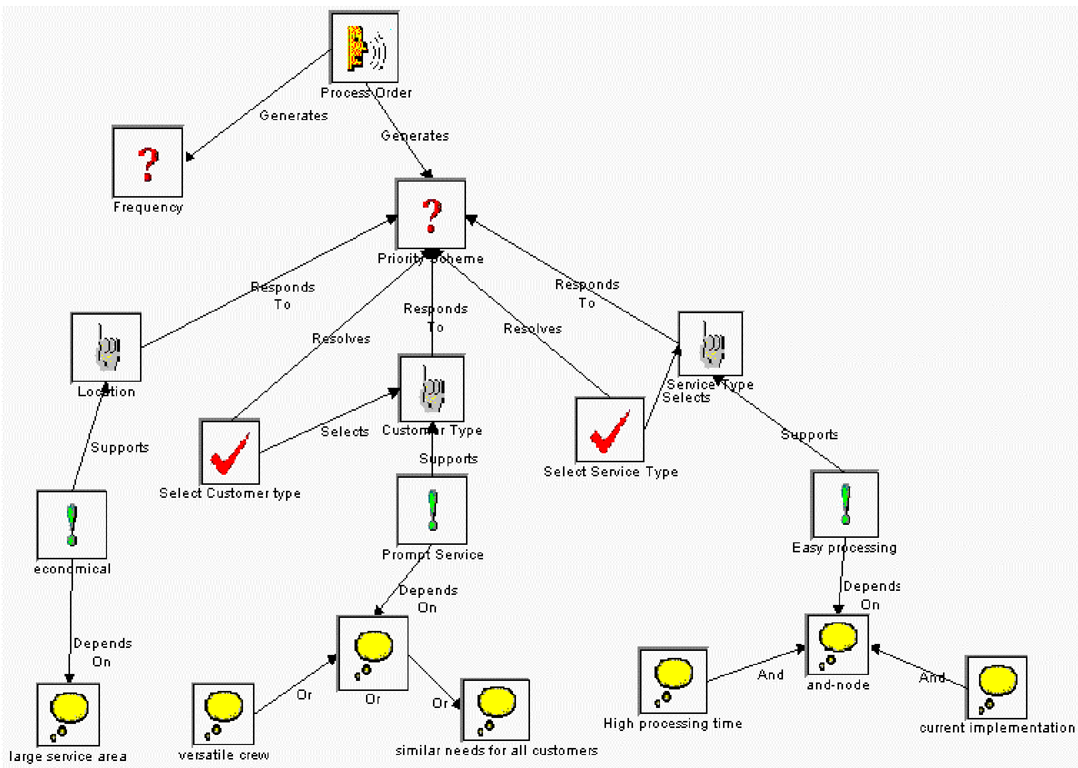
The above argument is based on the assumption that processing service orders of different kinds together will take lot of time for the crew compared to handling the same kinds of problems for various customers.

xii. Current implementation (assumption)

The argument that it is the easiest scheme to implement is also based on the assumption that it is the scheme currently in use and therefore will be the easiest to follow.

xiii. Select Customer type (Decision)

The decision arrived at by the design team is to go with a scheme that appears to provide the most effective service to the customers. This decision selects the alternative Customer type.



c. How Are Service Orders Tracked? (Issue) (Please see the figure below.)

The status of all service calls must be tracked and updated, to allow for timely customer notification. How these calls should be tracked is the issue.

i. CURRENT METHODS (alternative)

Currently, all calls are manually tracked by placing follow-up calls for every service tag generated. This method guarantees that all customers are given return calls updating them on the status of their service.

ii. MANUAL TRACKING (Argument)

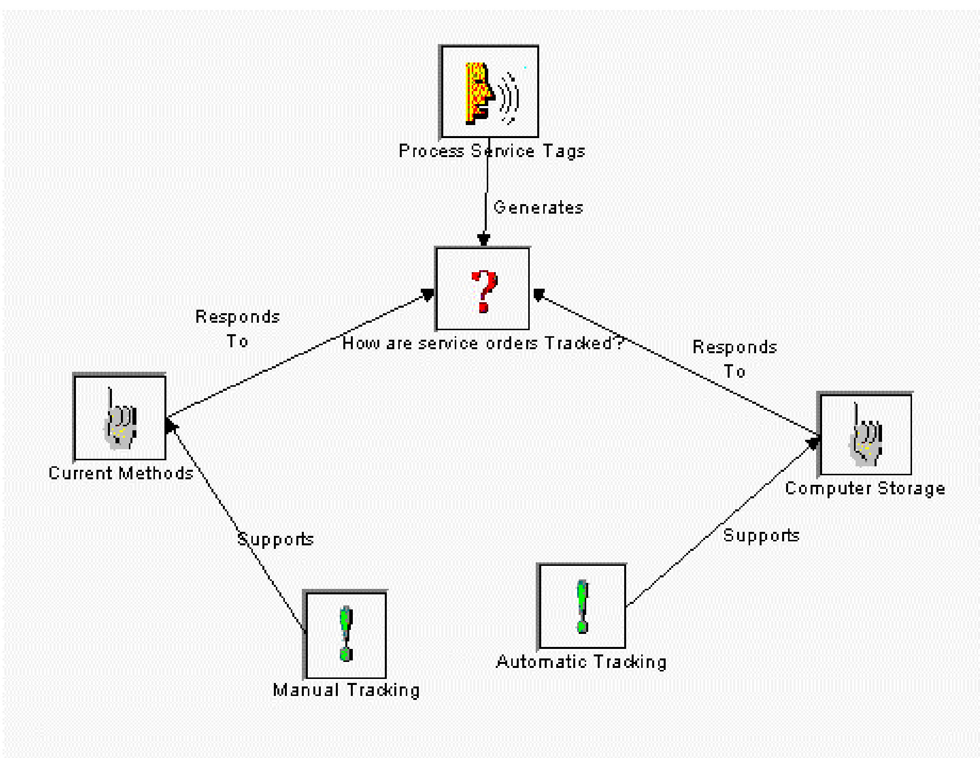
The current method of tracking orders is satisfactory, and performs well.

iii. COMPUTER STORAGE (alternative)

A database system of call storage should be implemented to help track orders.

iv. AUTOMATED TRACKING (Argument)

The new system should store calls on a centralized database without actually generating the tags. When service has been restored, the computer should be able to automatically dial the customer back, and let the operator update the customer. This will greatly reduce the time demands, because the tags will not have to be manually sorted and rechecked.



3.3. USING REMAP IN THE DESIGN PHASE

The following is an example use of REMAP during the design phase of system development. During this phase, the development team is engaged in discussions concerning the specific design mechanisms to process service tags. The issues being considered are:

How to get customer records?

How should the service operator's screen be organized?

How should service tags be screen?.

These deliberations identify and solve issues concerning the design phase of the project. Included in this section are descriptions of how the multimedia segments are incorporated.

1. Process Service Tags

Automating the processing of the service tags should provide the company with the following information:

Grid customer is on.

Feeder Number of customer.

Is this an isolated event or a global outage?

It is required that the system show that it can provide the above information faster and with fewer people involved in the process.

a. How to Get Customer Record? (Issue) (Please see the figure below.)

A customers record contains a variety of information. Customer address, phone number, and account number are the basics. Included in the record is what grid the customer is on, the feeder number, maintenance historical records, as well as all billing information. Some of this information is added to the newly generated tag. The issue is: How should the customers record be retrieved?

i. Entire Record (Position)

The entire record should be retrieved by the customer service operator at the time of the phone call. If a service tag is to be generated by the call, the appropriate information will be added to the tag at that time. The operator will be able to verify the correctness of the address as well.

If the call is a request for billing information, it can be handled at that time. All of the customer's information is already there. Not all of the information need be displayed at all times. The operator should have the ability to "drill down" to more detailed information as it is needed. For this reason, the information should be retrieved and ready to display for whatever the situation is.

ii. Better Customer Relations (Argument)

When a customer calls in, the call is posted on the Call Status Board. The operator has no idea of what the customer is calling about until she gathers more information. Because the operator is the main interface between the company and the customer, the operator should have quick and ready access to all of that customer's information. At any given time, the customer could be calling about a billing problem, a power outage, or a maintenance problem. For this reason, the operator needs to be able to instantly retrieve each of these types of data. The most efficient and expedient way of doing this is to retrieve the entire record as soon as the call is taken.

iii. Good Public Relations (Assumption)

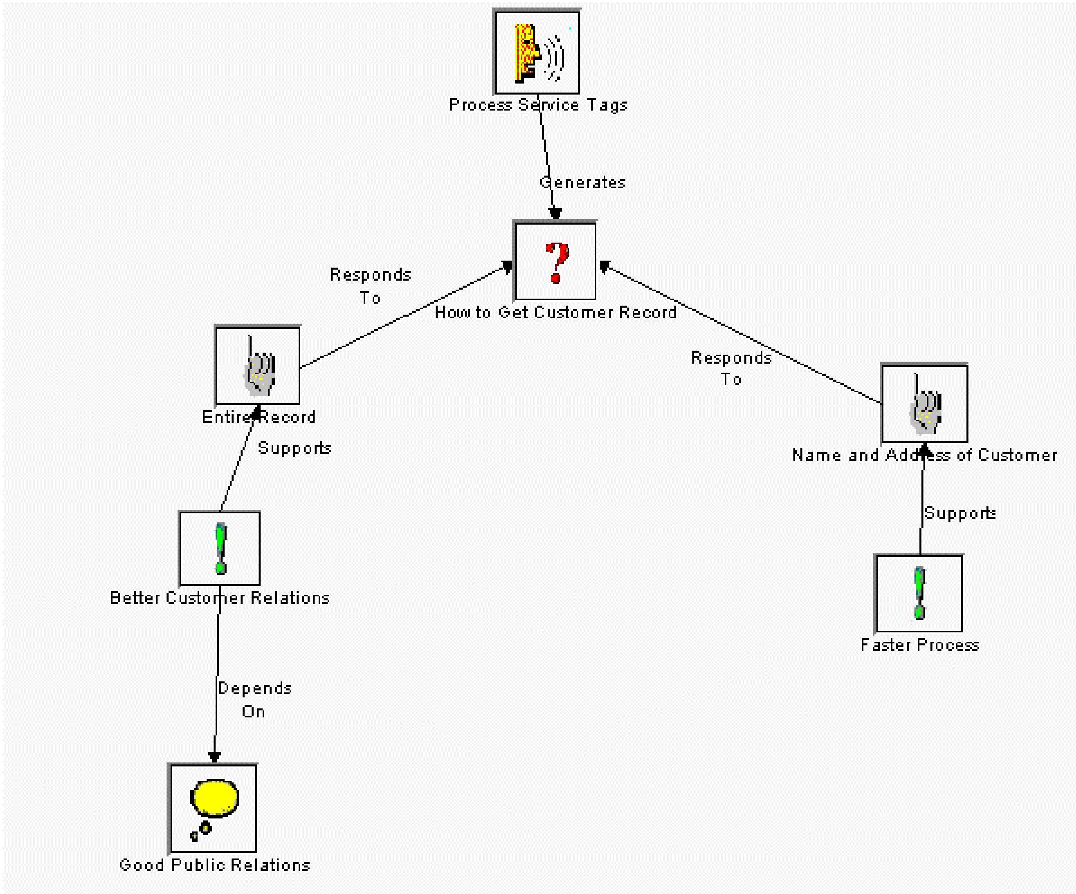
Good public relations is important in this industry due to constantly increasing costs. The operators are the primary communicators and representatives for the company, and hence must be capable of handling nearly any situation that could arise over the phone.

iv. Fill In Name And Address Of Customer (Position)

If a service tag is to be generated from this call, the information for the tag can be obtained during the tag processing, not during the phone call. Only the name, address, and phone number of the customer are needed and these can be obtained by the operator at that time. If there is a billing problem, then just the billing information of the customer needs to be retrieved.

v. Faster Process (Argument)

By not having to retrieve the entire customer record every time a phone call comes into the service operator center, more calls can be handled, providing better service to the customer.



b. How Should The Service Operator Screen Be Organized? (Issue) (Please see the figure below.)

Do the computer interfaces used by service operators need to be redesigned to better streamline the new automated process?

i. Categories For The Operator To Choose From (Alternative)

The screen used by the service operators should have a list of 9 to 10 categories for the operators to classify a maintenance request under.

ii. Current Tag Setup 9-10 Categories For The Operator To Choose From (Argument)

Ninety nine percent of all problems fall under these specified categories. The maintenance people will not use any more information than the basics anyway. This is also the current interface setup. No new training required.

iii. Operator Fill In Text (Alternative)

The screen should have the basic address information for the operator to confirm correct. Then have a text box for the service operator to type in a description of the problem. This will allow for precise descriptions of the problem, reducing the troubleshooting time required by the field workers.

iv. More Information (Argument)

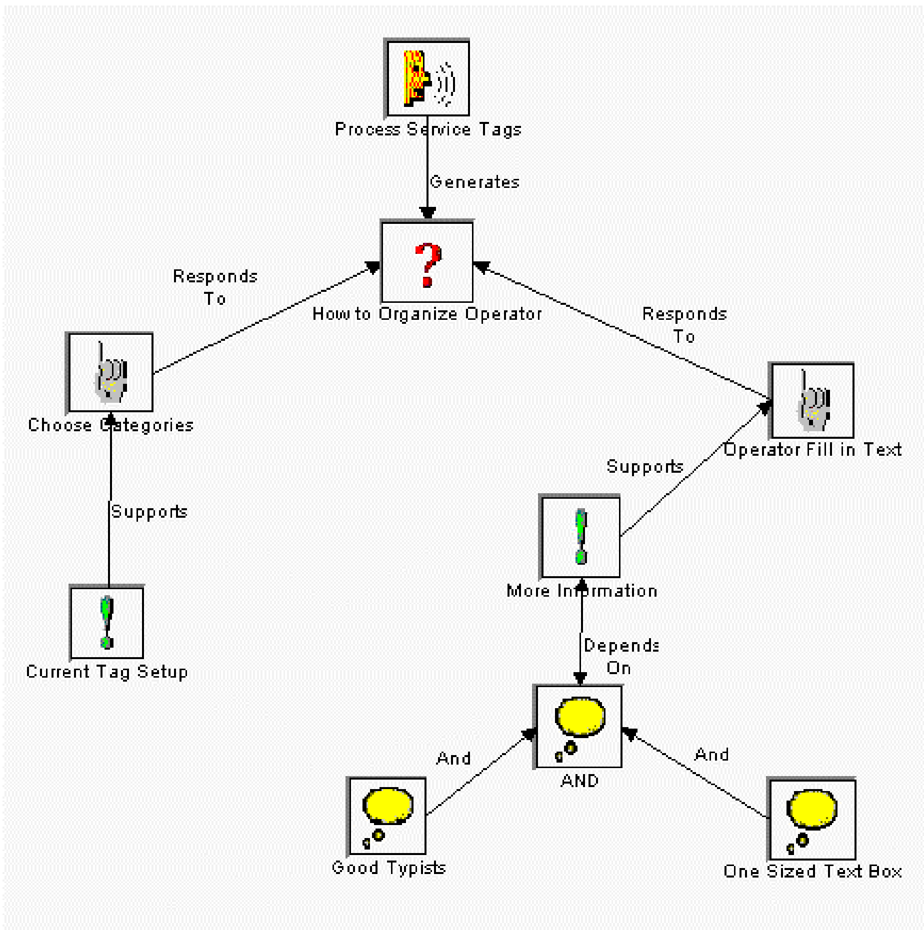
The more information describing the problem on the tag will help the maintenance people understand the problem better before actually talking to the customer themselves.

v. Good Typists (Assumption)

All the service operators are good typists, so this will not slow the process down any.

vi. One Sized Text Box (Assumptions)

One set sized text box will be able to handle any description made by a customer.



c. How Should The Service Tags Be Screened? (Issue) (Please see the figure below.)

The manual screening process that is used currently is just too slow. This process must be automated. Each tag will have on it the customers' grid number, as well as source side device tag number. The database must be able to screen the tags and sound an alert if there seems to be a global outage occurring.

i. Screen All Tags Generated In The Last 30 Minutes (Alternative)

If a tag for a complete electrical failure is generated, it needs to be compared to any tag with a similar complaint to determine if this is an isolated event or not. If not, then there is a possibility of a global failure. One method suggested to determine this would be to compare the tag to those tags generated in the last 30 minutes.

ii. Fewer Tags Generated (Argument)

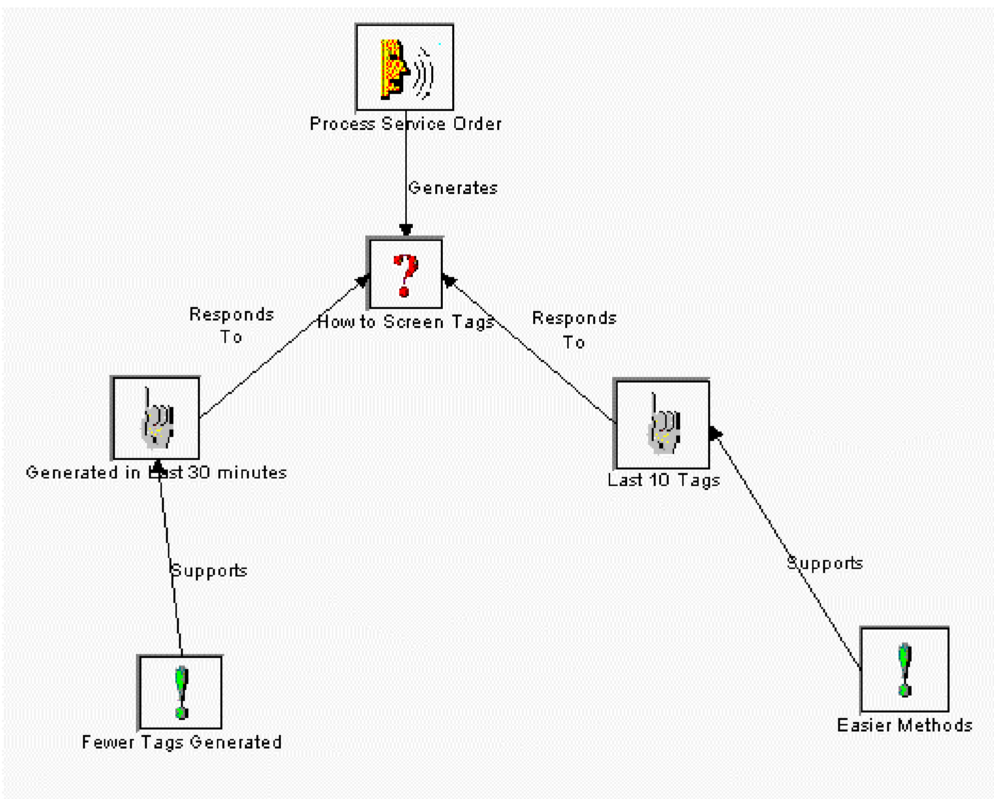
This comparison will allow fewer tags to be generated if there is a global outage.

iii. Last 10 Tags (Alternative)

Power failure tags need to be compared with the last 10 tags regardless of time in order to detect a global failure.

iv. Easier Method (Argument)

This is an easier method to implement and it gets the same job done. Fewer tags will be generated.



Appendix 2: REMAP Legend

The following diagram illustrates the Icons, their interrelations: